

The background of the slide is a dark reddish-brown color. On the left side, there is a partial view of a bright, textured sphere, likely representing the Sun. To the right of the Sun, there are several concentric, glowing white and yellow lines that curve around a central point, representing magnetic field lines or solar wind patterns. The overall effect is a stylized representation of space weather phenomena.

# **Space Weather**

**Indiana Space Day, March 28, 2009**

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# Weather on Earth



- Precipitation
- Light Displays
- Power of Nature
- Societal Danger



# **Weather in Space?**



- **Precipitation**
- **Light Displays**
- **Power of Nature**
- **Societal Danger**

## **Shock and Awe?**

# Roadmap

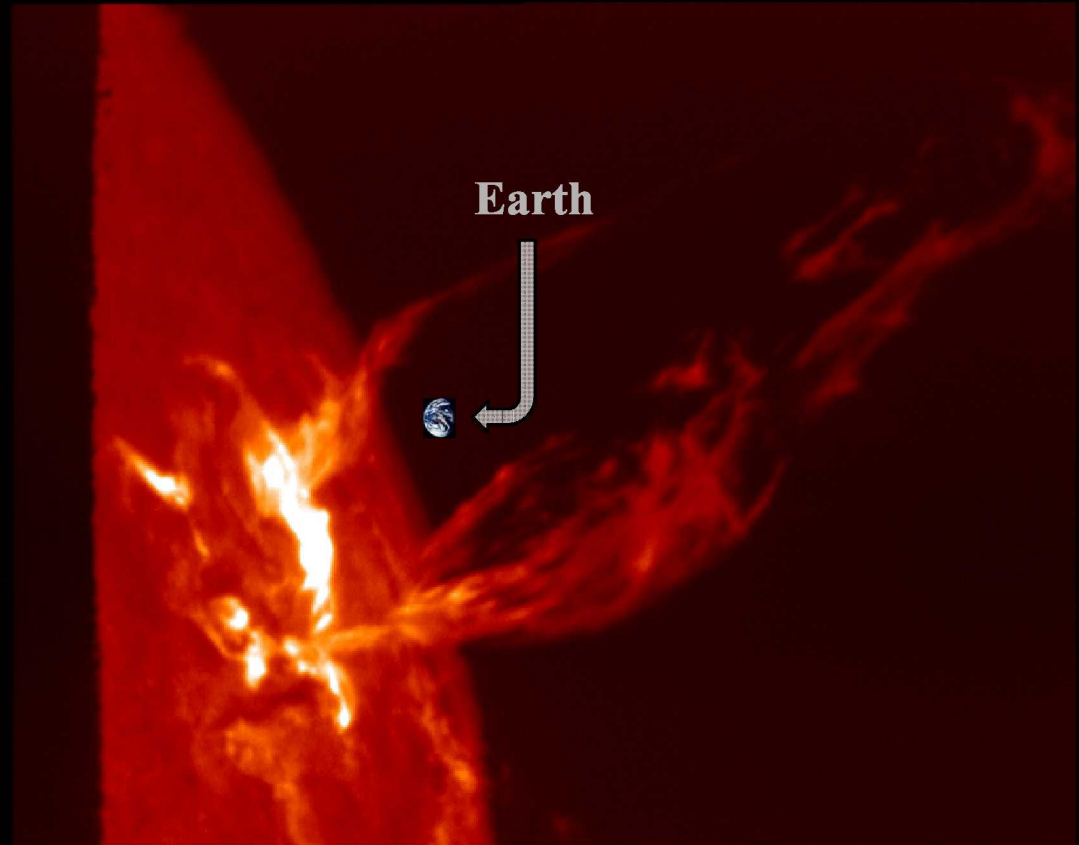
- Hazards and effects to humans and manmade systems?
  - In space
  - In the air
  - On the ground

# Start at the Sun

## Flare or Coronal Mass Ejection:

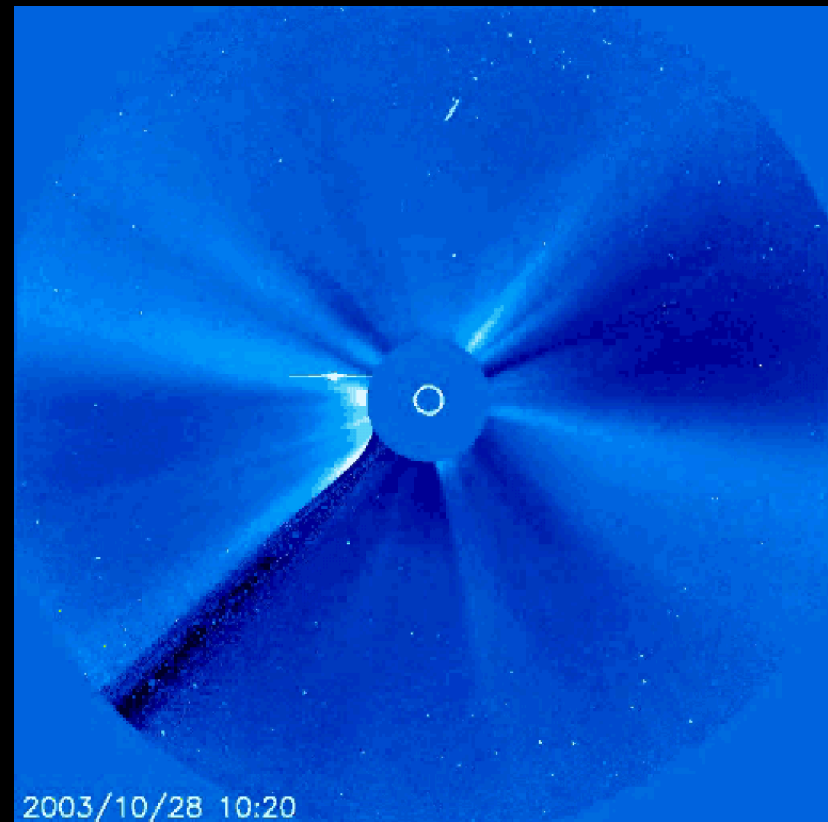
**Violent release of as much a billion tons of matter.**

**Can be equivalent of 40 billion Hiroshima-sized atomic bombs.**



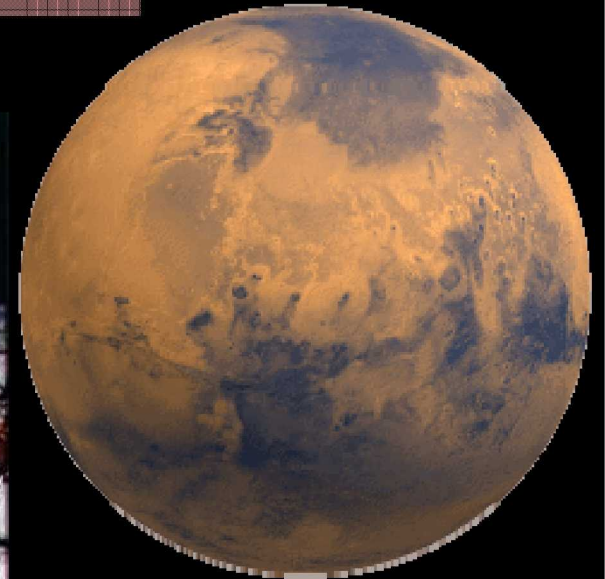
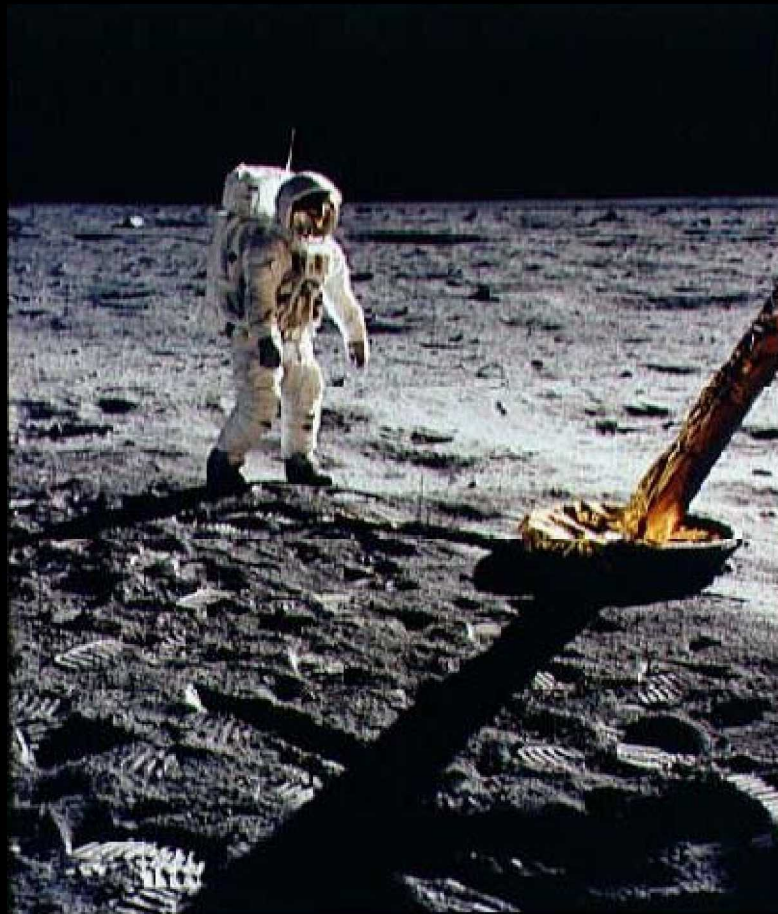
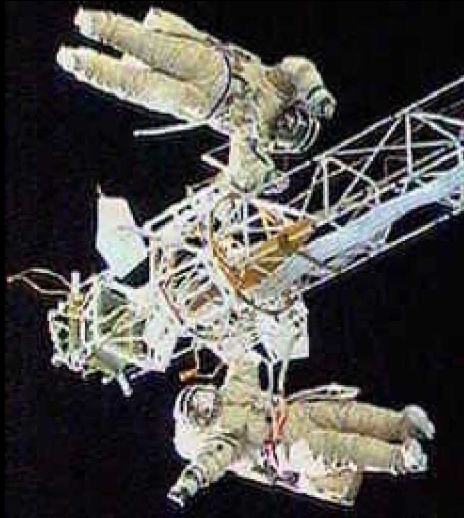
# Weather at the Sun or Elsewhere Means There are Events

- What do you see?
- Near the Sun?
- Far from the Sun?

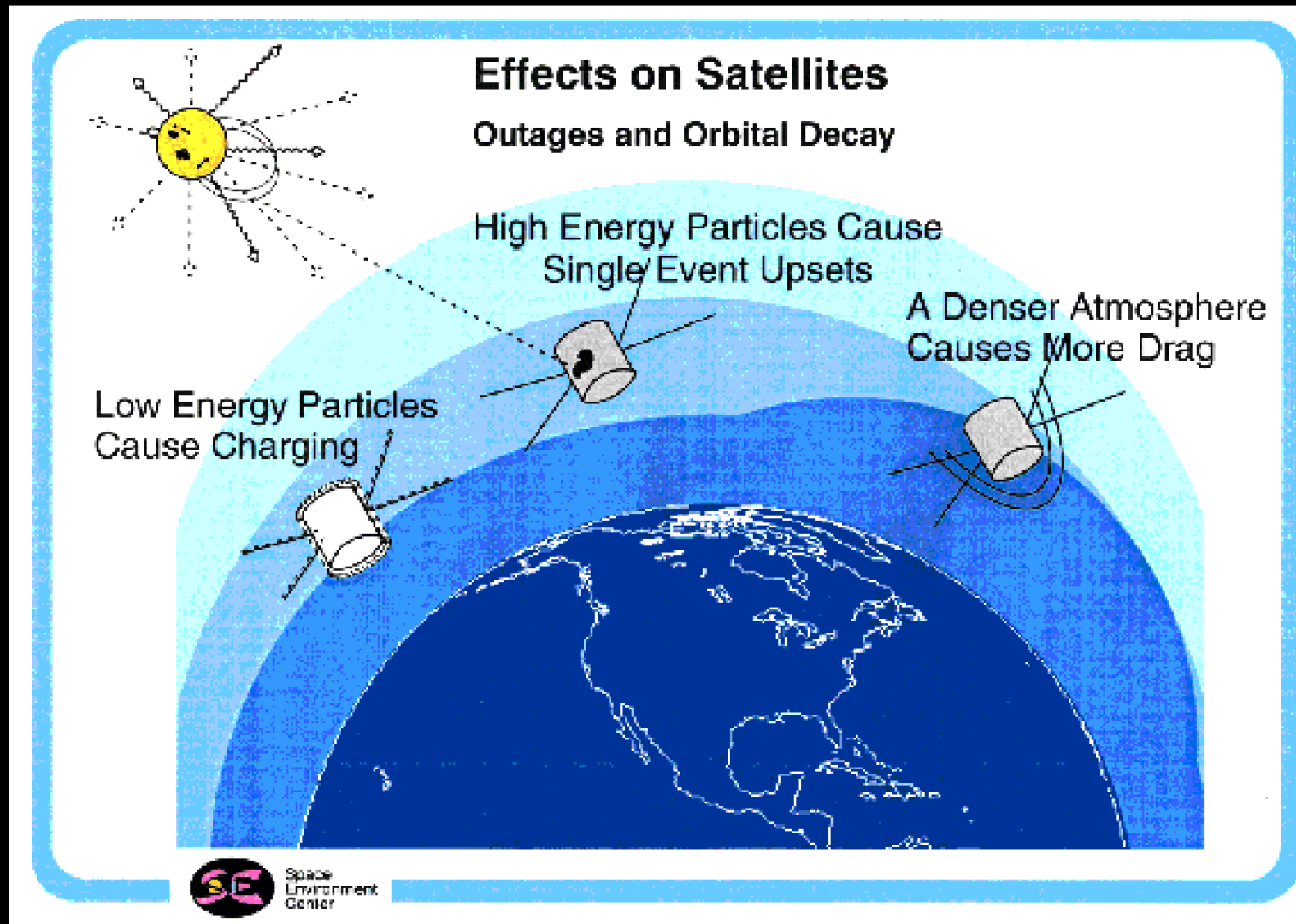


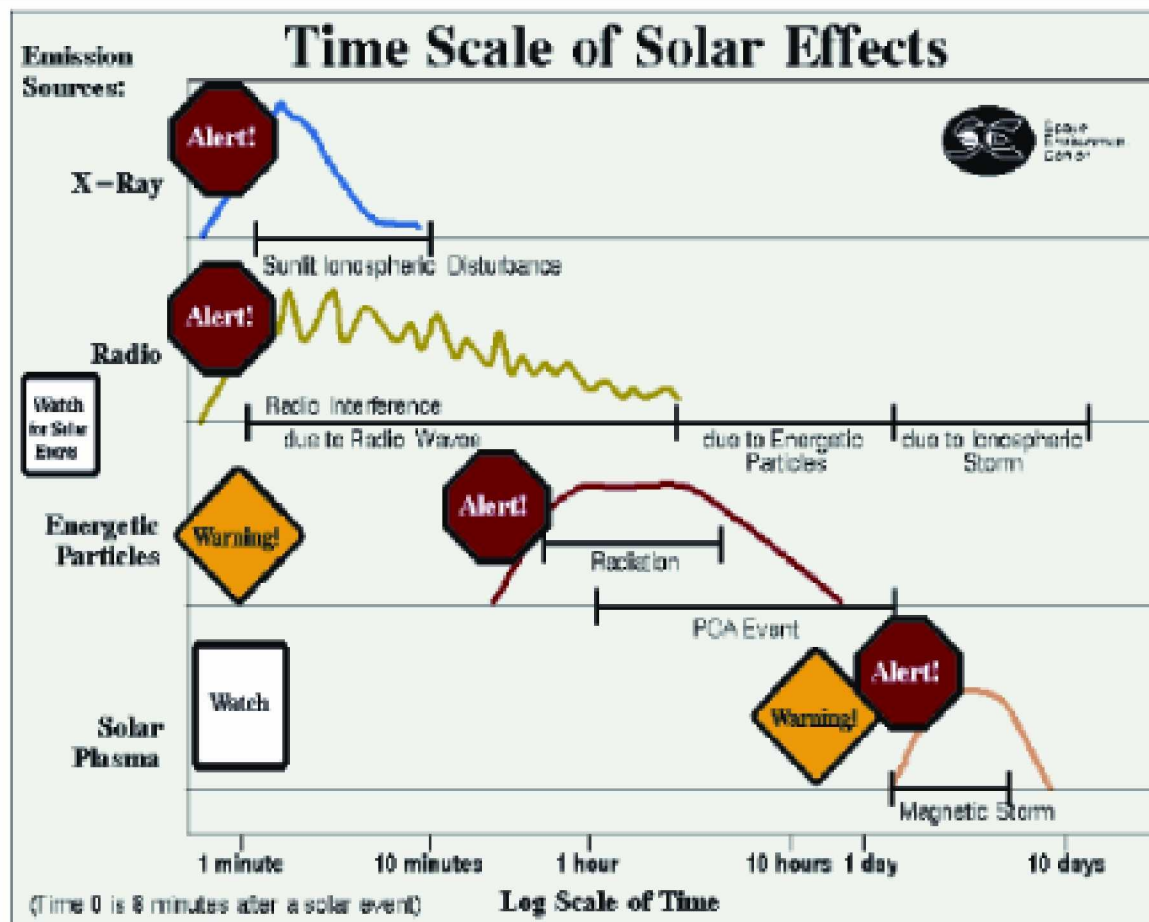
2003/10/28 10:20

# Hazards to Humans in Space



# Satellite Hazards



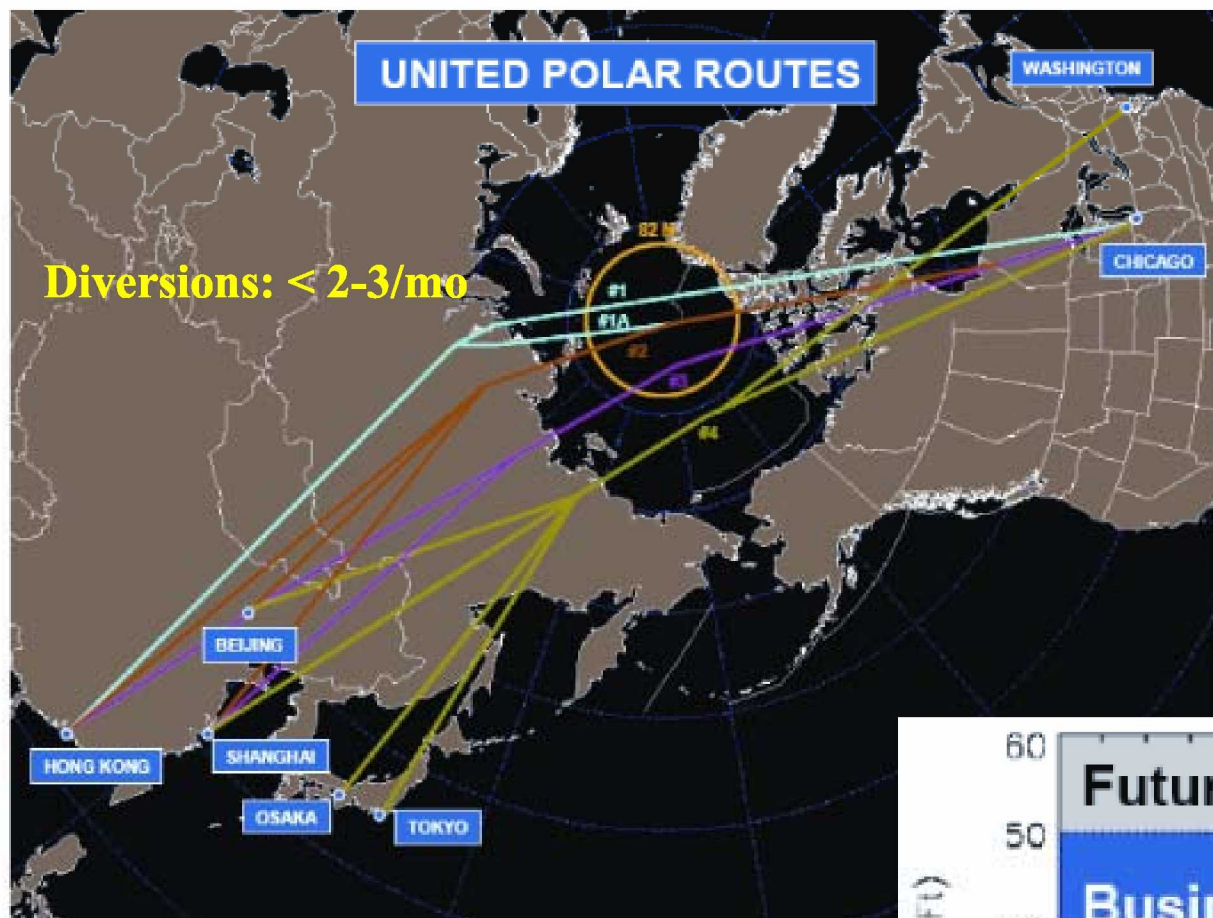


**Figure 2. The time scales of solar effects (source: NOAA SEC). Eight minutes after a flare and/or a CME erupts from the Sun, the first blast of Extreme Ultraviolet (EUV) and X-ray light increases the ionospheric density, which can impact HF communication loss. 10 minutes to several hours later, energetic particles arrive. One to four days later, the CME passes and energizes the magnetosphere and ionosphere, affecting navigation systems and radio communications.**

**From the American Meteorological Society & SolarMetrics Policy Workshop Report March 2007**

# Risks for Electronics

- In space single event upsets (SEU) cause satellite control errors, risking damage or loss
- In aircraft SEU's cause upsets of about 1 per 200 hours of operation measured on a Boeing 777 autopilot: (designed for 1:1 million); pacemakers have been used to measure SEU's in commercial aircraft
- On the ground SEU's are thought to have caused power losses in German high-speed trains in the 1990's from cosmic radiation.

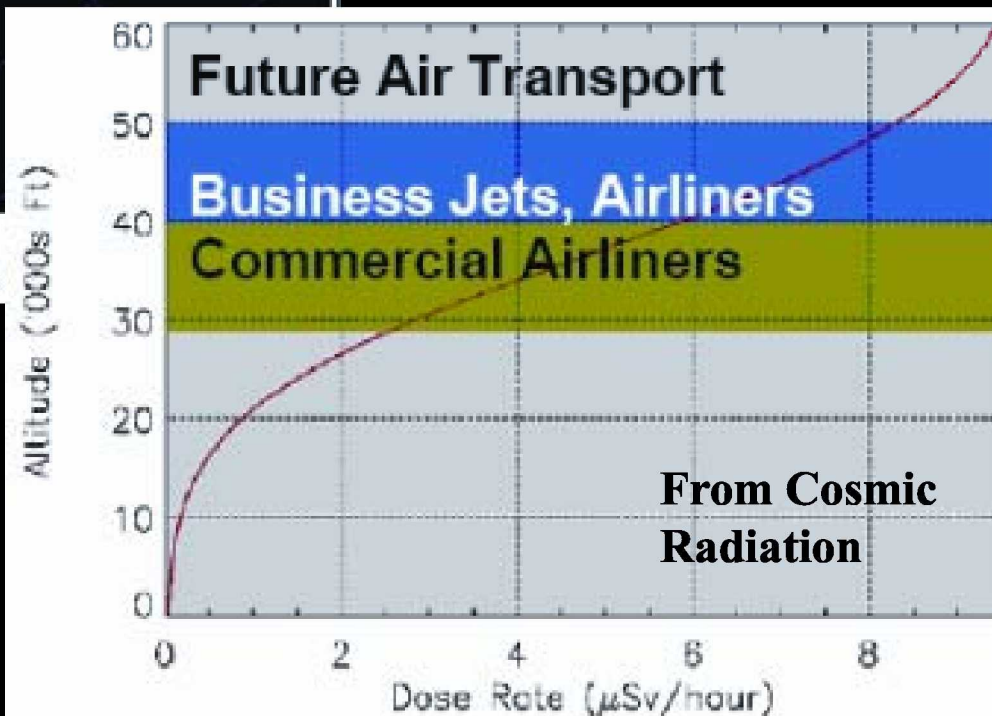


**Transpolar  
Flights and  
cosmic  
radiation risks  
are increasing**

Figure 1. Polar Routes used by United Airlines (source:

**From the American  
Meteorological Society &  
SolarMetrics Policy Workshop  
Report March 2007**

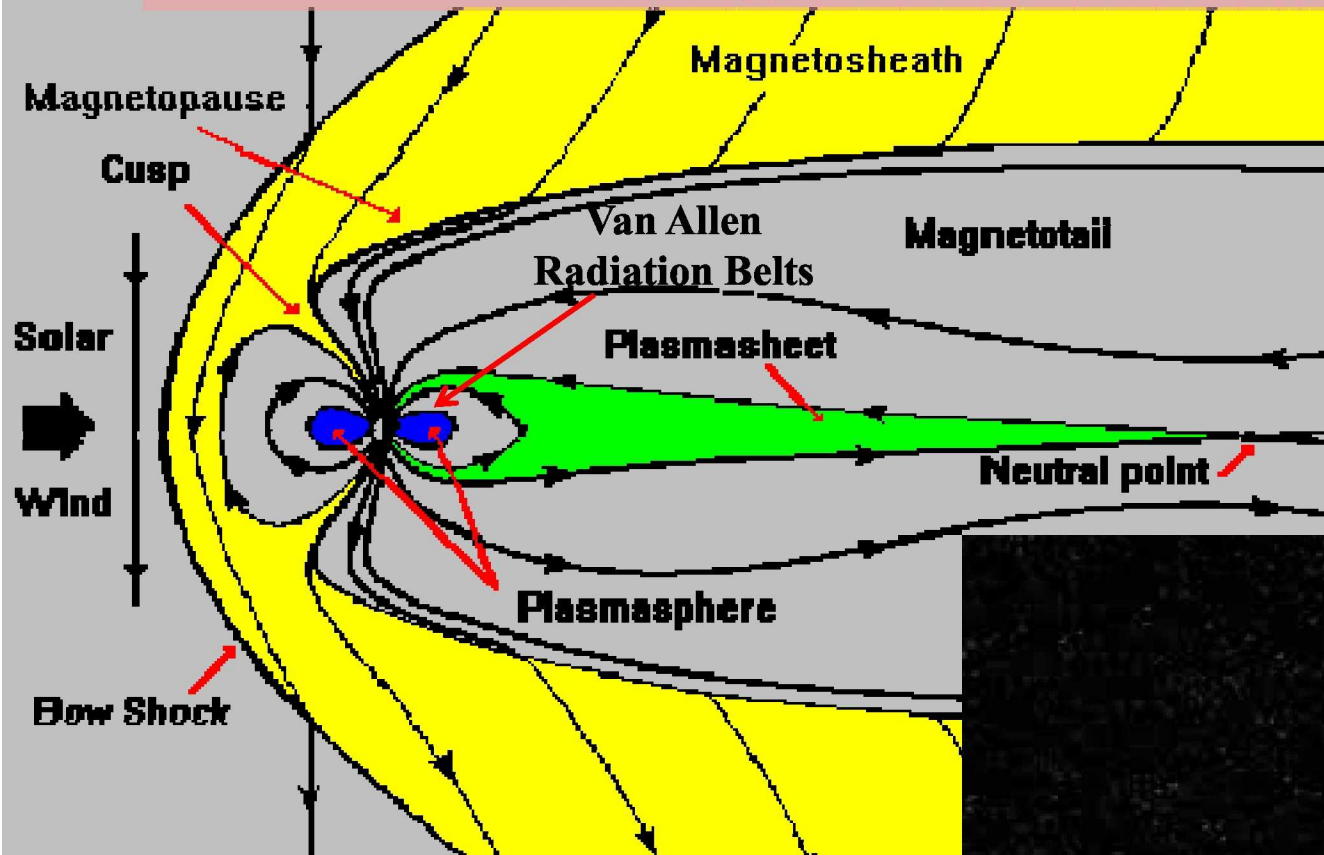
**Max permissible mean dose  
rate limit: 7.5 mSv/hour**





**Fairbanks, Alaska**

# Earth's Magnetic Environment



Precipitation  
Electric Currents  
Ionospheric scintillation  
10MW radio emission  
Radiation

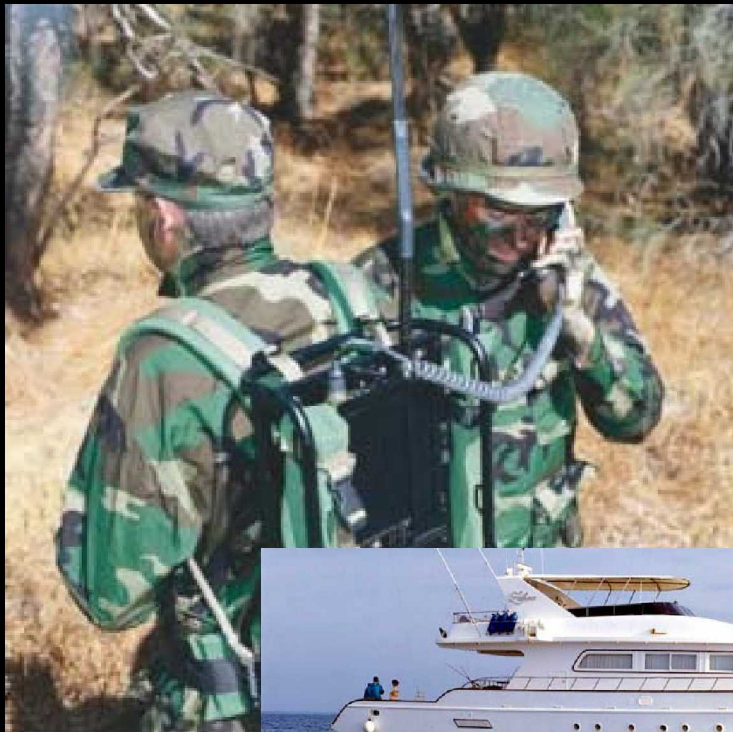
The  
Magnetosphere



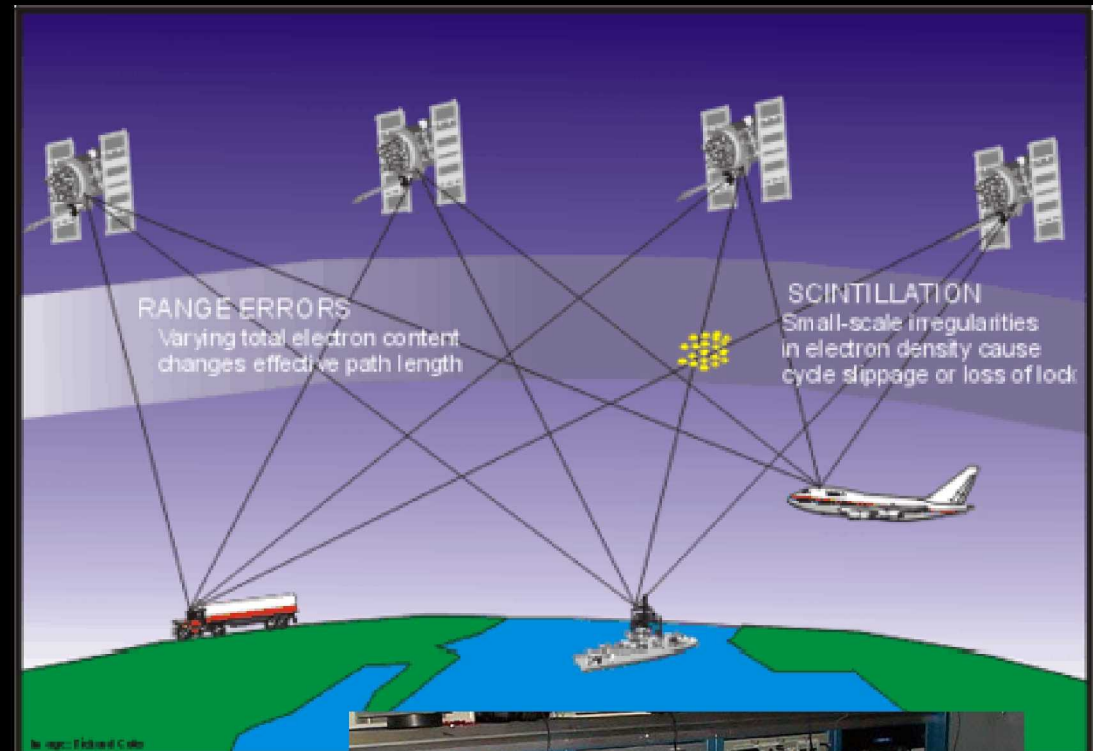
# Disruption of:

# HF

# Communication



# Navigation



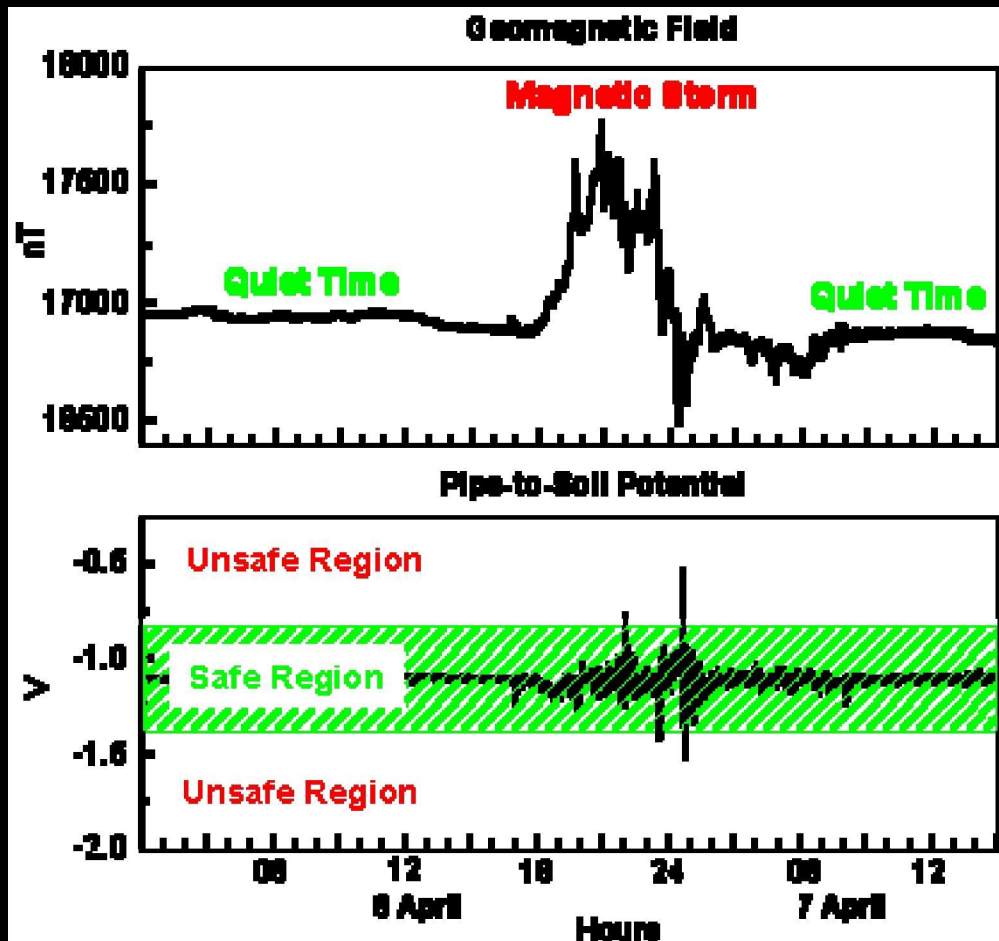
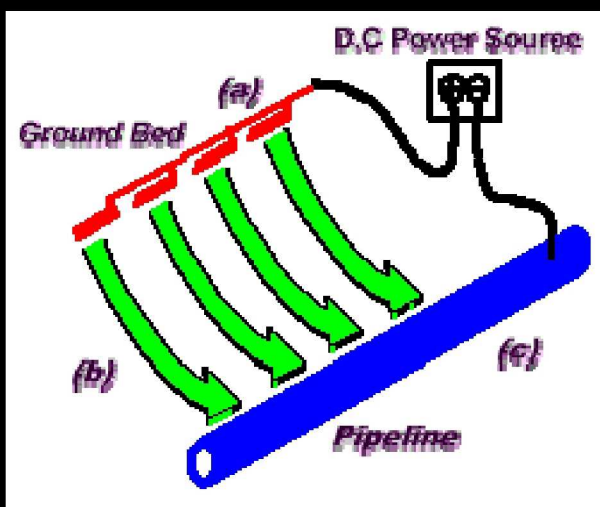
# Ground Induced Currents (GIC)

- GIC's hamper rail traffic by disturbing signaling systems. In Sweden in 1982, railway signals failed to switch correctly; induced voltage may cause such a malfunction; 19 lives were lost in Norway in January 2000 due to flawed "track clear" signal during heightened solar activity, although not proven.
- GIC's are thought to generate hundreds or even thousands of volts on deep sea communication cables during geomagnetic storms; even fiber optic cables are metal clad and there are cables to carry current to the amplifiers

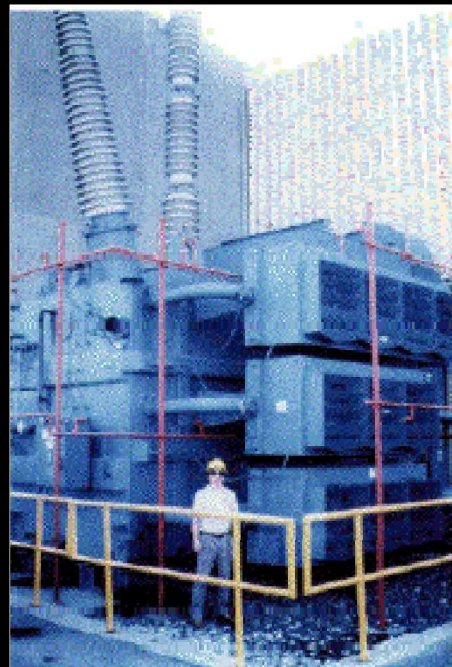


# Pipeline-Soil Potentials Advance Corrosion

**Telluric currents  
disrupt cathodic  
protection**

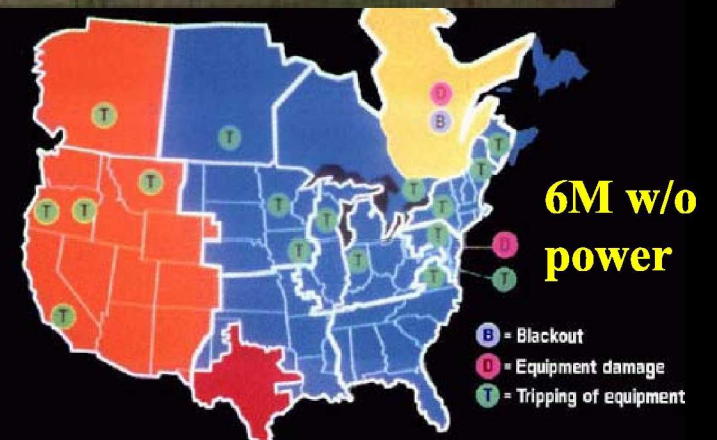
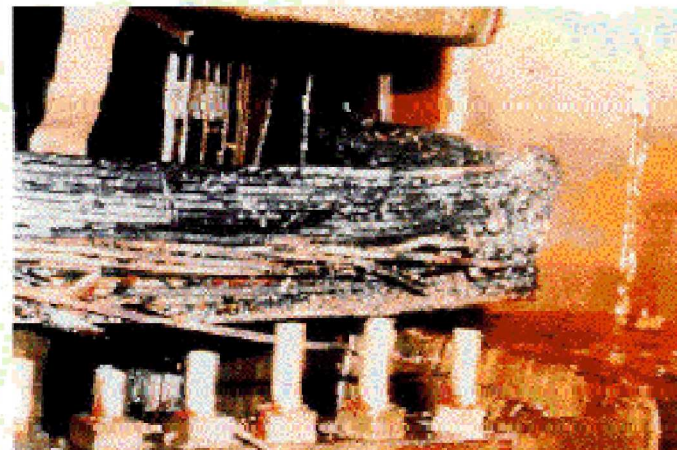


# Electrical Power Disruption Due to Induced Electric Currents

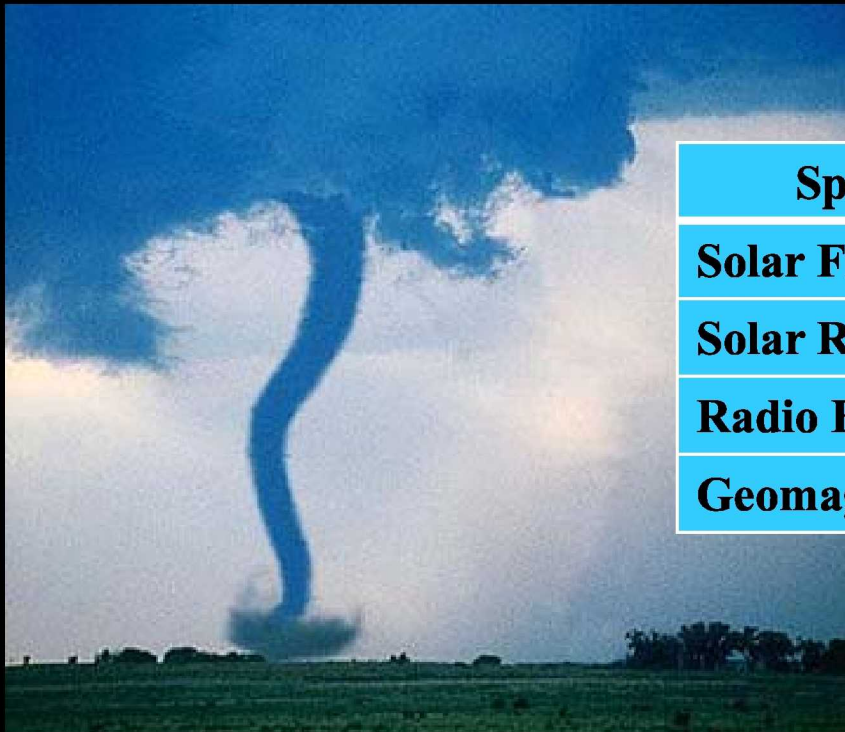









**PJM Public Service  
Step Up Transformer**

Severe internal damage caused by  
the space storm of 13 March, 1989.



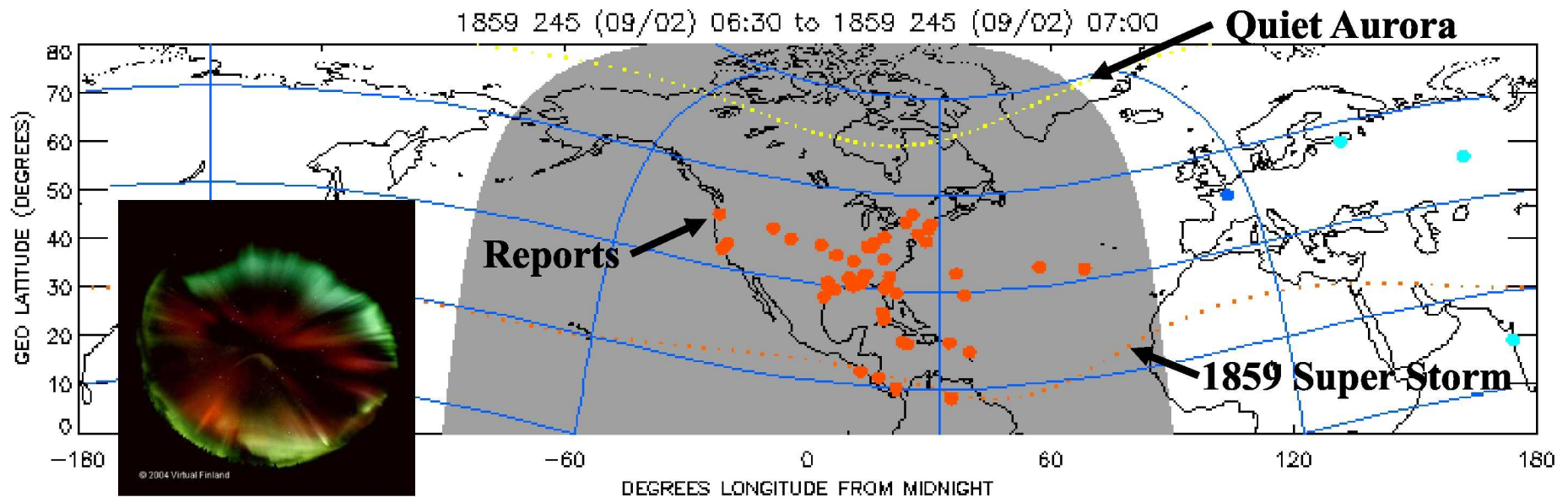
Atmospheric storms have categories.  
Don't space storms too?



Space Storm	Minor  Extreme
Solar Flares	B  C  M  X
Solar Radiation	S1  S5
Radio Blackouts	R1  R5
Geomagnetic Storms	G1  G5

# September 2, 1859 Event

**3X recent storm strength / 1/3 strongest ever**

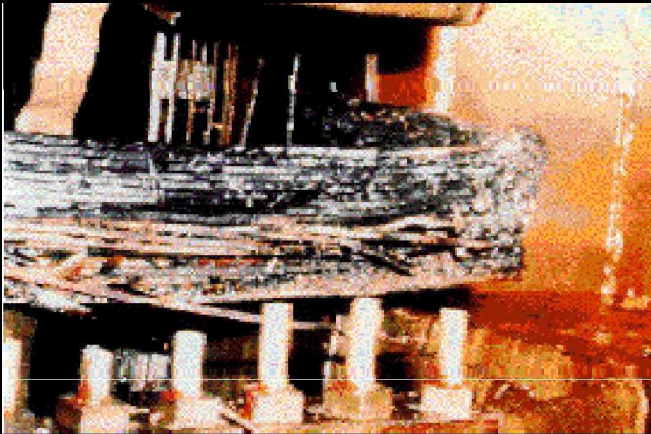


- Messenger (deck log: Lat. 49°) “we witnessed the most magnificent display of the aurora boreales (sic) imaginable ... the whole firmament was a blaze of Crimson shooting up from all points of the compass but the most splendid from the South W. I have not the language to describe it”

Courtesy James L. Green, NASA/GSFC

# Weather in Space

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## Shock and Awe

